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ORIGINAL ARTICLE

Endodontic infections in a Portuguese population with self-reported cardiovascular disease - a cross-sectional study

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Aim: *To assess the prevalence of apical periodontitis, root-filled teeth, and related covariates, considered potential risk factors for cardiovascular diseases in patients with a self-reported cardiovascular disease history, who first attended the Faculty of Dentistry, University of Porto, in 2018.*

Methodology: *Out of 2,063 reviewed medical and dental records, 1,841 individuals met the inclusion criteria. Endodontic infections and oral status were assessed through orthopantomography. Cardiovascular disease classification was based on self-reported diagnosis. Medical history included dichotomous data on hypertension, diabetes mellitus, and smoking. Bivariate analyses were conducted using Student's t-test for quantitative variables and Pearson's Chi-square test for categorical variables (95% CI, $\alpha = 0.05$). Multivariate logistic regression assessed the impact of confounders on the presence of apical periodontitis and root-filled teeth. Statistical significance was set at $p < 0.05$.*

Results: *The prevalence of apical periodontitis and root-filled teeth was 72% and 57% in patients with cardiovascular diseases, and 45.6% and 47.8% in those without. Bivariate analysis revealed significant associations between cardiovascular disease and age, gender, number of teeth, apical periodontitis, hypertension, diabetes, and smoking. No significant association was found between cardiovascular disease and root-filled teeth. In the multivariate model, the association between apical periodontitis and cardiovascular disease was no longer statistically significant.*

Conclusion: *Although the prevalence of apical periodontitis and root-filled teeth was higher in patients with self-reported cardiovascular disease, no significant association was observed. Hypertension and smoking emerged as key risk factors for cardiovascular disease. Further research is warranted to clarify the potential link between endodontic infections and cardiovascular conditions.*

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Introduction

Apical periodontitis (AP) is an immunoinflammatory reaction of the periradicular tissues to a polymicrobial infection originating in the root canal system, often leading to bone resorption (1). It is a highly prevalent oral condition, affecting nearly half of the adult population (2). The prevalence of AP is higher in individuals with systemic conditions (63%) compared to healthy individuals (48%) (2). Its occurrence has increased over the past decade in both endodontically treated and untreated teeth (3). Diabetes mellitus, cardiovascular diseases (CVDs), and smoking were identified as significant factors influencing AP prevalence (2). Overall, AP affects approximately 5% to 6.3% of all teeth. In root-filled teeth (RFT), the prevalence is higher, around 7.4%, with 39%–41% of individuals presenting at least one RFT showing signs of AP. In contrast, untreated teeth show a lower prevalence, ranging from 3% to 3.5% (2, 3).

Endodontic treatment is commonly performed worldwide, with an estimated 8.2% of all teeth having undergone root canal therapy. Approximately 56% of individuals have at least one RFT, reflecting the widespread use of this treatment (4). The success of endodontic therapy can be influenced by systemic conditions such as diabetes mellitus, smoking, and hypertension (5), which may impair periapical healing (6, 7). Additionally, the overall oral inflammatory load—including the number of carious lesions, residual roots, and remaining teeth—may contribute to a systemic pro-inflammatory state, potentially increasing cardiovascular risk (6).

CVDs are a leading global public health concern, responsible for approximately 19.1 million deaths in 2020 (8). This group of disorders affects the heart and blood vessels, including conditions such as coronary heart disease, stroke, peripheral artery disease, and rheumatic heart disease. CVDs significantly impact quality of life and healthcare systems, with a prevalence of 48.6% among adults, rising with age. In 2020, deaths from heart disease and stroke surpassed those from cancer and chronic respiratory diseases (9). Common risk factors include diabetes mellitus, smoking, and hypertension (10, 11).

Hypertension has long been recognized as a major risk factor for fatal cardiac disorders. Endodontists should be aware of the systemic implications of endodontic procedures and the need for multidisciplinary management, making it essential to stay updated on current guidelines and ensure proper blood pressure control before dental treatment (12).

Recent studies have investigated the potential bidirectional relationship between endodontic infections, and systemic diseases, highlighting the complex interplay between local and systemic inflammatory processes (13). However, the underlying mechanisms remain a subject of debate, largely due to the presence of various confounding factors (14-16). Several findings support a biologically plausible link between endodontic inflammation and cardiovascular outcomes, including the presence of gram-negative anaerobes, local release of pro-inflammatory cytokines, and elevated systemic inflammatory markers and endothelial activation in patients with AP—features also associated with atherosclerosis and acute cardiovascular events (17, 18). Nonetheless, the evidence remains insufficient to establish a conclusive association.

Thus, this cross-sectional study primarily aimed to assess the prevalence of AP and RFT in patients with self-reported CVDs who first attended the Faculty of Dental Medicine of the University of Porto in 2018. A secondary objective was to evaluate other known covariates, including the number of carious lesions, the number of teeth and residual roots present, as well as systemic conditions considered potential risk factors for CVDs. The null hypothesis stated that patients with self-reported CVDs would not exhibit a higher prevalence of AP or

RFT, nor be more affected by their oral inflammatory status, compared to individuals without self-reported CVDs.

Materials and Methods

Patient's selection

The present study analysed data from 2,063 medical and dental records from the Faculty of Dental Medicine of the University of Porto. Data were collected from all patients attending their first-ever appointment for routine dental care at the faculty's pedagogic clinic in 2018. To avoid data duplication, only first-time visits were included. The study was approved by the institution's ethics committee (research project 9/2025) and conducted in accordance with the STROBE guidelines for observational studies (19). Only patient data that met the study's inclusion criteria were used (n=1,841), that is, individuals over 18 years old, with more than eight teeth, complete clinical records, and digital panoramic radiographs. Patients who did not meet these criteria were excluded from the study (n=222). The CVD group of diseases was classified according to the World Health Organization Guidelines Subcommittee's criteria (8). However, the patient data included were based on self-reported diagnoses. Patients who did not self-report any form of CVD and had their first appointment at the Faculty of Dental Medicine of the University of Porto during the same period served as the non-CVD group.

Data collection

Sociodemographic (age and gender) and medical variables were collected. Systemic conditions like hypertension, diabetes mellitus, and smoking habits were recorded from the medical history using a dichotomous response (yes/no). Regarding smoking habits, patients were categorized as non-smokers if they had never smoked and smokers if they were current or former smokers, according to other studies (20). As for hypertension, to apply stricter inclusion criteria, only patients who were taking anti-hypertensive medication were considered (20).

Two qualified endodontists with 20 years of clinical experience (NV and IM) examined panoramic radiographs on a computer screen, blinded to the patient's medical histories. All teeth, except third molars and dental implants, were assessed. For each patient, the following variables were evaluated: the number of RFT, number of teeth with AP, prevalence of teeth with AP in RFT (RFT-AP), prevalence of teeth with AP but without root fillings – designated as untreated teeth with AP (UT-AP), number of teeth present, number of teeth with caries or restorations (designated as caries experience), and number of residual roots. Teeth were classified as RFT if any radiopaque material was visible in the root canals. The prevalence of AP, RFT, RFT-AP, and UT-AP was determined by calculating the percentage of individuals with at least one affected tooth. The oral status was described based on the number of teeth present, caries experience, and number of residual roots, per individual, following the methodology of previous studies (21, 22).

Periapical Status Assessment and Radiographic Evaluations

The condition of the periapical tissues was evaluated using the periapical index of Orstavik (PAI) (23). AP was diagnosed when the scores were greater than two (PAI ≥ 3). For multi-rooted teeth, the highest recorded score was considered the tooth's PAI score. All panoramic radiographs were taken using an Orthoralix® 9200 DDE (Gendex) orthopantomograph and assessed with VixWin Platinum® software, which allows for adjusting the image size and contrast.

Examiner`s Calibration

Previously, the examiners participated in a PAI system calibration course (23), which involved independently evaluating the radiographs twice. Intraobserver reproducibility was assessed by scoring the radiographs of 50 patients, randomly selected, and two months after the initial examination, re-scoring the same radio-

Table 1
Characteristics of the examined variables per individual in the total sample (SD, standard deviation; AP, apical periodontitis; RFT, root-filled teeth; RFT-AP, root-filled teeth with apical periodontitis; UT-AP, untreated teeth with AP).

Table 2
Prevalence and types of cardiovascular diseases (CVDs) (8) self-reported in the study population

Table 3
Prevalence of individuals with self-reported systemic conditions associated with cardiovascular risk factors.

graphs. Cohen's kappa values of 0.70 and 0.72 were calculated. The interobserver calibration for PAI yielded a Cohen's kappa of 0.71. In cases of disagreement a senior professor (IPV) joined the discussion to reach a consensus.

Statistical Analysis

Data were recorded in Microsoft Excel (Microsoft Corporation) and then imported into IBM SPSS Statistics (Version 30.0; IBM Corp.). For descriptive statistics, results were expressed as mean ± standard deviation (SD) for continuous variables and as frequency and percentage for categorical data. Bivariate analyses of quantitative variables between the CVD and non-CVD groups were performed using the student's t-test, while categorical variables were analyzed using Pearson's Chi-square test (CI 95%, $\alpha = 0.05$). The effect of potential confounding factors on the risk of AP and endodontic status (RFT) was assessed using multivariate logistic regression. In accordance with the established significance level, a p-value <0.05 was considered statistically significant.

Results

Data from 1,841 patient records were analysed in this study (Table 1). The average age was 43.8 ± 17.6 years, with women having an average age of 43.0 ± 17.2 years and men 45.1 ± 17.9 years.
The prevalence of individuals with CVDs in the sample was 5.8% (n=107). Table 2 shows the frequencies and types of CVDs identified in the studied population, according to the WHO (8).
Table 3 shows the prevalence of self-reported systemic conditions related to the occurrence of CVDs (risk factors for CVDs).
Table 4 shows the distribution of the examined variables between the CVD and non-CVD groups and analyzes their association with CVDs.
In the CVD group, 72% of individuals had at least one tooth with AP (prevalence of AP), and 57% had at least one RFT (prevalence of RFT). In comparison, the non-CVD group showed prevalence's of 45.6% for AP and 47.8% for RFT. The difference in AP prevalence between the groups was statistically significant, while the difference in RFT prevalence was not. However, significant differences were found between the CVD and non-CVD groups in the prevalence of individuals with at least one RFT with AP (RFT-AP), as well as those with at least one untreated tooth with AP (UT-AP). To examine variables related to oral status (number of teeth present, caries experi-

Variables	Total
Age (years), mean ± sd	43.8 ± 17.6
Gender, n (%) - Male	761 (41.3)
Gender, n (%) - Female	1080 (58.7)
Number of teeth with AP, mean ± sd	0.9 ± 1.3
Prevalence of AP, n (%)	867 (47.1)
Number of RFT, mean ± sd	1.2 ± 2.0
Prevalence of RFT, n (%)	889 (48.3)
Prevalence of RFT-AP, n (%)	494 (26.8)
Prevalence of UT-AP, n (%)	561 (30.5)
Number of teeth present, mean ± sd	23.8 ± 5.1
Caries experience, mean ± sd	5.4 ± 4.6
Number of residual roots, mean ± sd	0.4 ± 2.0

Table 1

Cardiovascular Diseases	Frequency, n (%)
Stroke	61 (57.0)
Myocardial infarction	18 (16.8)
Cardiac arrhythmia	15 (14.0)
Heart failure	6 (5.6)
Aneurysm	3 (2.8)
Others	4 (3.8)

Table 2

CVDs-systemic related conditions	Frequency, n (%)
Hypertension, n (%)	377 (20.5)
Diabetes mellitus, n (%)	123 (6.7)
Smoking Habits, n (%)	698 (37.9)

Table 3

Variable	CVD group (n=107)	Non-CVD group (n=1734)	p value
Age (years), mean ± SD	60.9 ± 13.7	42.8 ± 17.2	<0.001*
Gender, n (%)			0.010*
Male	57 (53.3)	704 (40.6)	
Female	50 (46.7)	1030 (59.4)	
Number of teeth with AP, mean ± SD	1.8 ± 1.6	0.9 ± 1.3	<0.001*
Prevalence of AP, n (%)	77 (72.0)	790 (45.6)	<0.001*
Number of RFT, mean ± SD	1.3 ± 1.8	1.2 ± 1.8	0.161
Prevalence of RFT, n (%)	61 (57.0)	828 (47.8)	0.063
Prevalence of RFT-AP, n (%)	39 (36.4)	455 (26.2)	0.021*
Prevalence of UT-AP, n (%)	60 (56.1)	501 (28.9)	<0.001*
Number of teeth, mean ± SD	19.4 ± 6.1	24.1 ± 4.9	<0.001*
Caries experience, mean ± SD	5.7 ± 4.9	5.4 ± 4.5	0.242
Number of residual roots, mean ± SD	0.6 ± 1.2	0.4 ± 2.1	0.236
Hypertension, n (%)	67 (62.6)	310 (17.9)	<0.001*
Diabetes, n (%)	20 (18.7)	103 (5.9)	<0.001*
Smoking Habits, n (%)	57 (53.3)	103 (37.0)	<0.001*
*statistical significance (p<0.05)			

Table 4
Distribution of the examined variables in the CVD and non-CVD groups. (SD, standard deviation; AP, apical periodontitis; RFT, root-filled teeth; RFT-AP, root-filled teeth with AP; UT-AP, untreated teeth with AP).

ence, and number of residual roots), a Student's t-test was conducted to evaluate differences in the mean values between the CVD and non-CVD groups. Significant differences were found in the mean number of teeth present between the two groups. Regarding variables representing risk factors for CVDs, such as hypertension, diabetes, and smoking habits, significant differences were also observed between the CVD and non-CVD groups.
To identify the factors associated with periapical status (AP prevalence), a multivariate logistic regression analysis was performed using a forward stepwise method.
The dependent variable was "periapical status" (0 = no teeth with AP; 1 = at least one tooth with AP). Age, gender, number of teeth, caries experience, number of residual roots, presence of at least one RFT, presence of CVD, hypertension, diabetes mellitus, and smoking habits were the independent variables included in the analysis. In the final model, a statistically significant positive correlation is shown in Table 5. The number of teeth present showed a statistically significant negative correlation with AP, with a higher number of teeth being associated with a reduced likelihood of having AP.
Finally, a multivariate logistic regression was performed to assess the factors associated with the dependent variable "endodontic status" (0 = no RFT; 1 = at least one RFT). The independent variables included in the model were: age, gender, number of teeth, caries experience, number of residual roots, presence of AP, presence of CVD, hypertension, diabetes mellitus, and smoking habits.
Age (OR = 1.0; 95% CI = 1.012–1.025; p<0.001), female gender (OR = 0.7; 95% CI = 0.578–0.916; p = 0.007), prevalence of AP (OR = 3.1; 95% CI = 2.472–3.961; p < 0.001) and caries experience (OR = 1.3; 95% CI = 1.283–1.371; p < 0.001) were found to be significantly associated with the presence of RFT.

Discussion

The hypothesis that AP may be associated with systemic conditions, particularly CVDs, is supported by cross-sectional and longitudinal studies as well as biologically plausible mechanisms.

					95% C.I. for OR	
Independent variables	B	SE	p value	OR	LL	UL
Age (years)	0.013	0.005	0.005*	1.014	1.004	1.023
Gender	0.115	0.015	0.338	1.121	0.887	1.418
Caries experience	0.101	0.064	<.001*	1.106	1.075	1.139
No. of residual roots	0.229	0.015	<.001*	1.257	1.109	1.424
No. of teeth	-0.074	0.118	<.001*	0.928	0.902	0.955
Smoking Habits	0.895	0.181	<.001*	2.447	1.941	3.087
Diabetes	0.208	0.149	0.392	1.231	0.765	1.981
Hypertension	0.488	0.127	0.007*	1.629	1.144	2.321
CVD	0.124	0.504	0.629	1.132	0.684	1.873
No. of RFT	1.155	0.005	<.001*	3.174	2.474	4.072
Constant	-0.767	0.015	0.128	0.465		
**statistical significance (p<0.05)*						

Table 5
Multivariate logistic regression analysis of factors associated with AP using forward stepwise selection (B, logistic regression estimated coefficient; S.E., estimated standard error for the estimated coefficient; p value, value associated with the statistical coefficient test; OR, estimated odds ratio; CI, confidence interval of 95% for odds ratio; LL, lower limit; UL, upper limit).

This cross-sectional study aimed to assess the prevalence of AP and RFT in a Portuguese population attending their first appointment at the Faculty of Dentistry, University of Porto, in 2018, and to explore their association with self-reported CVDs. The recruitment followed a methodology similar to that used in previous studies in Portugal (24-26) and internationally (21, 22). The inclusion of 1,841 patients provide a relatively large sample size, which strengthens the reliability and consistency of the observed associations. As in related studies (20, 22,26-28), we excluded patients with fewer than eight teeth, a criterion likely to reduce the risk of diagnostic confounding between endodontic and periodontal conditions.

The overall prevalence of AP in our study was 47.1%, per individual, consistent with recent systematic reviews and meta-analyses (2, 3). Compared to the previously reported prevalence of 44.2% in a Portuguese population in 2014 (25), our findings suggest a stable but slightly increasing trend. This pattern is in line with the findings of Razdan, Jungnickel (29), who observed a rise in the relative frequency of AP in a Danish population over a 10-year period (1997–2007). While a declining trend in RFT was observed in the Danish population (29), our study found a 48.3% prevalence of RFT (compared to 47.2% in 2014), suggesting that the prevalence of both AP and RFT in Portuguese samples has remained relatively stable over the past decade (25). A 2012 Portuguese study reported lower rates of AP and endodontic treatment, possibly reflecting a less conservative endodontic approach, where increased extractions may have reduced the observed prevalence of AP (26).

A cone-beam computed tomography (CBCT) study conducted in a Scottish sub-population, using data collected from 2009 to 2012 (30), reported AP in 5.8% of 3,595 teeth assessed from dentate patients over 18 years of age. With a similar methodology, a study in Portugal analyzing scans from eight private health centers (2012–2018) found an overall AP prevalence of 10.4% per tooth (31). While highlighting the superior diagnostic accuracy of CBCT compared to conventional radiographs, the authors noted that this prevalence still falls within the range (1.4%–15.1%) reported in earlier studies using either panoramic radiographs (32, 33) or CBCT (30, 34). In line with these findings, a previous Portuguese study using panoramic radiographs (26) reported an AP prevalence of 1.7% (PAI ≥ 3) across 5,552 teeth. More recently, systematic reviews and meta-

analyses based on panoramic radiographs estimated global AP prevalence at 6.3% (3) and 5.0% (2) per tooth.
A significant association was observed in the bivariate analysis between CVDs and both the number of teeth with AP and the prevalence of AP, defined as the presence of at least one affected tooth per individual. In contrast, no significant association was found between CVDs and either the number or prevalence of RFTs. However, after adjusting for potential confounders in the multivariate model, the association between AP and CVDs lost statistical significance. These findings contrast with those reported by Caplan, Pankow (35), who, in a prospective study, found that individuals with a higher self-reported history of endodontic treatment and with 25 or more teeth were more likely to have coronary heart disease. Similarly, the Baltimore Longitudinal Study (36) identified endodontic burden—defined as the combined presence of AP and RFT—as an independent mid-life predictor of cardiovascular events. Nonetheless, both studies highlight the need for prospective research to better understand the epidemiology of endodontic infection and to assess whether treating AP might reduce cardiovascular risk. It is important to note that differences in methodology may influence the variables assessed and partially explain these inconsistencies.
Similarly, in a pair-matched cross-sectional study An, Morse (21) using medical and dental chart review (full-mouth radiographs) from hospital records, a bivariate association between AP and CVDs was reported. Supporting these findings, González-Navarro, Segura-Egea (22) also identified a significant association between AP and atherothrombotic cardiovascular events in a matched study using clinical exams and panoramic radiographs. Corroborating the present study, RFT were not significantly associated.
Unlike the aforementioned studies (21, 22), which used electronic medical records and ICD-9-CM codes to confirm CVD diagnoses, our study relied on self-reported health data. Although common in epidemiological research, self-reported information has known limitations, particularly in the accuracy of medical and dental history, as individuals may be unaware of past or existing conditions, leading to possible misclassification. Nevertheless, this method remains an accepted approach for assessing both AP, RTF and CVD status (2, 35, 37). Age differed between the CVD and non-CVD groups and is associated with AP, RFT, CVD, and related risk factors, representing a potential confounder. Although this is a study limitation, not matching for age (and gender) allowed us to explore their possible influence as effect modifiers. As in most epidemiological studies assessing the prevalence of AP (3), we relied on panoramic radiographs for diagnosis. Although CBCT offers greater sensitivity (38), it is not yet considered the standard imaging modality for population-based research. The most recent position statement from the European Society of Endodontology (ESE) recommends CBCT only for specific clinical indications (39). Therefore, conventional radiography remains the primary diagnostic tool in epidemiological contexts, even though it may underestimate the true prevalence of AP (38). To address the limitation of not conducting clinical examinations, periapical status and the prevalence of RFT were assessed using panoramic radiographs. This method considered appropriate for epidemiological research (2), may help explain, along with other methodological differences, the discrepancies observed across studies. Despite a moderate Cohen's kappa value (40), the reliability of the radiographic assessment—conducted by two senior dentists specialized in Endodontics and blinded to participants' systemic and oral health status—was reinforced by the involvement of a third senior endodontist, who resolved any discrepancies by consensus.
A secondary objective of this study was to investigate additional oral and systemic factors associated with CVD risk. Significant associations were observed

between CVDs and variables such as age, number of teeth with AP, number of untreated AP lesions, and total number of teeth, indicating a poorer oral health among individuals with CVDs. The complexity of the oral microbiome still poses significant challenges, particularly regarding the role of microorganisms and their metabolites in oral infections and subsequent tissue inflammation (41). Elevated levels of pathogenic bacteria in dental plaque trigger an exaggerated immune response. Bacterial components, such as lipopolysaccharides (LPS), stimulate the production of inflammatory mediators and cytokines, which in turn activate matrix metalloproteinases (MMPs) responsible for degrading the extracellular matrix and promoting bone resorption. These pathological processes extend beyond the oral cavity, impacting systemic health. Endothelial dysfunction, an early marker and independent predictor of cardiovascular events, underscores the need for a broader understanding of these mechanisms to enable prevention and reduce the healthcare burden (42).

These findings are consistent with previous studies (21), which reported associations between CVDs and indicators of compromised oral health, including missing teeth, caries, and the number of RFTs. Supporting this evidence, Cotti and Mercuro (43) linked endodontic infections and poor oral health to early vascular changes and increased CVD risk. Similarly, González-Navarro, Segura-Egea (22) emphasized the role of cumulative oral inflammatory burden, including caries, periodontal disease, AP, and furcation lesions, in relation to CVDs, distinguishing it from metabolic syndrome (MetS), a systemic condition marked by hypertension, hyperglycemia, and abdominal obesity, which also contributes significantly to cardiovascular risk.

Several factors have been identified as influencing AP prevalence: country income level (with higher rates in developing countries), setting of recruitment (with higher rates in dental care services), presence of systemic conditions, study quality and risk of bias, radiographic method (e.g., higher prevalence in CBCT-based studies), and diagnostic criteria (e.g., lower prevalence when using stricter PAI thresholds). These findings underscore the need for greater awareness among health policymakers and professionals regarding the often-overlooked burden of endodontic disease at the population level (2). Although previous studies have suggested a potential link between chronic endodontic infections and CVD, the overall quality of evidence remains limited (10). Globally, diabetes mellitus, smoking, and hypertension are recognized as major CVD risk factors (44). Diabetes mellitus is a widespread condition and was among the first systemic diseases investigated for associations with endodontic infection. While many studies have shown that AP can both worsen and be exacerbated by diabetes mellitus, results remain inconsistent (45). In our bivariate analysis, hypertension and smoking were significantly associated with both CVDs and AP ($p < 0.05$), whereas diabetes was significantly associated with CVDs, but not a predictor for AP.

Comorbidities like smoking and hypertension were also more prevalent in the CVD group. Smoking has been linked to a pro-inflammatory state, impaired immune function, and delayed healing, which may contribute to the development of AP. Previous studies have reported an association between smoking and increased AP incidence (46, 47), likely due to enhanced bone resorption and reduced pulp defense. However, the literature remains inconclusive. An, Morse (21) found no association between smoking and AP, although they did report links with hypertension, caries, missing teeth, and RFTs. Similarly, González-Navarro, Segura-Egea (22) observed no significant differences in smoking or diabetes status between CVD and control groups. In contrast, Portuguese studies have shown a positive association between smoking and AP. Correia-Sousa, Madureira (24) reported a general link, while Melo, Ferreira (25) identified a significant association with multiple AP lesions (≥3; $p = 0.025$). However, neither Melo´s study nor the present one found a significant association between smoking and RFT prevalence, diverging from earlier findings by Correia-Sousa's (24). Supporting the broader role of smoking in endodontic outcomes, Krall, Abreu Sosa (48) reported that current smokers were 1.7 times more likely to undergo root canal treatment than never-smokers. A later study (20) reported AP in 92% of hypertensive patients who also smoked. Together, these findings reinforce the potential impact of hypertension and smoking on periapical health and support the associations observed in our study.

A key finding of the current Portuguese investigation was the strong association between CVDs and hypertension, a well-established major risk factor for atherosclerosis and related conditions (49). Hypertension was defined according to the criteria established by Caplan, Pankow (35) and Segura-Egea, Castellanos-Cosano (20) using self-reported antihypertensive medication use to improve diagnostic reliability. Other studies have similarly used thresholds of systolic blood pressure ≥130 mmHg, diastolic ≥85 mmHg, or current treatment to define hypertension (22). An association between hypertension and AP was also observed, aligning with previous findings (21, 22). Although severe cardiovascular conditions may not have been prevalent in this sample, the notable proportion of hypertensive individuals under medication (20.5%) underscores the importance of early detection and management. Given hypertension's modifiable nature, proactive intervention remains critical in reducing the burden of CVDs (49).

Hypertensive individuals had 1.629 times higher odds of presenting with AP ($p < .005$), while smokers had 2.447 times higher odds ($p < .001$). Importantly, our findings should not be interpreted as evidence of causality. As emphasized by Jiménez-Sánchez, Cabanillas-Balsera (50) the association does not imply causality. Shared risk factors between CVDs and endodontic disease may act as confounders, introducing bias into the observed associations. Inconsistencies across studies may be explained by variations in methodology, participant characteristics, sample sizes, diagnostic criteria for AP and CVDs, and statistical approaches. Additionally, unmeasured confounding variables, such as socioeconomic status, access to healthcare, and oral health behaviors, may have influenced the results in different ways (2). Longitudinal studies with standardized methodology, although crucial for assessing temporality and dose–response relationships, face practical challenges such as dropout rates and methodological variability. Thus, despite the inherent limitations of cross-sectional studies, they remain valuable for identifying potential risk indicators in diverse populations, thereby informing and guiding future longitudinal research.

Conclusions

Our findings confirm the high prevalence of endodontic infections, with nearly half of the assessed individuals presenting at least one tooth with AP and one RFT. This supports the general trend of a stable or slightly increasing prevalence over the past decade. However, no strong evidence was found linking AP or RFT to CVDs. Individuals with CVDs also showed poorer overall oral health. The broad definition of CVD and the reliance on self-reported medical data were among the limitations of the present study. However, the large sample size and the strict criteria for hypertension underscored the significance of this often silent condition. Notably, AP was significantly associated with smoking and hypertension, both well-established risk factors for atherosclerosis and cardiovascular events. Given the rising burden of CVDs, hypertension, smoking, and AP, further longitudinal and interventional studies are warranted to clarify potential causal relationships and guide preventive strategies.

Conflict of interest
None.

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Referencess

1. *Siqueira JF, Jr., Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. Journal of endodontics. 2008;34(11):1291-301.e3.*
2. *Tibúrcio-Machado CS, Michelon C, Zanatta FB, Gomes MS, Marin JA, Bier CA. The global prevalence of apical periodontitis: a systematic review and meta-analysis. International endodontic journal. 2021;54(5):712-35.*
3. *Jakovljevic A, Nikolic N, Jacimovic J, Pavlovic O, Milicic B, Beljic-Ivanovic K, et al. Prevalence of Apical Periodontitis and Conventional Nonsurgical Root Canal Treatment in General Adult Population: An Updated Systematic Review and Meta-analysis of Cross-sectional Studies Published between 2012 and 2020. Journal of endodontics. 2020;46(10):1371-86.e8.*
4. *León-López M, Cabanillas-Balsera D, Martín-González J, Montero-Miralles P, Saúco-Márquez JJ, Segura-Egea JJ. Prevalence of root canal treatment worldwide: A systematic review and meta-analysis. International endodontic journal. 2022;55(11):1105-27.*
5. *Cabanillas-Balsera D, Areal-Quecuty V, Cantiga-Silva C, Cardoso CBM, Cintra LTA, Martín-González J, et al. Prevalence of apical periodontitis and non-retention of root-filled teeth in hypertensive patients: Systematic review and meta-analysis. International endodontic journal. 2024;57(3):256-69.*
6. *Segura-Egea JJ, Cabanillas-Balsera D, Martín-González J, Cintra LTA. Impact of systemic health on treatment outcomes in endodontics. International endodontic journal. 2023;56 Suppl 2:219-35.*
7. *Cunha ILM, Martins IEB, de Oliveira JWC, Hanan SA, Herkrath FJ, Júnior ECS. Postoperative Pain Following Endodontic Treatment in Patients With Type 2 Diabetes Mellitus: A Prospective Non-Randomized Clinical Trial. Giornale Italiano di Endodonzia. 2025;39(2):14-23.*
8. *WHO. Cardiovascular diseases (CVDs) [Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).*
9. *Tsao CW, Aday AW, Almarzooq ZI, Anderson CAM, Arora P, Avery CL, et al. Heart Disease and Stroke Statistics-2023 Update: A Report From the American Heart Association. Circulation. 2023;147(8):e93-e621.*
10. *Koletsi D, Iliadi A, Tzanetakis GN, Vavuranakis M, Eliades T. Cardiovascular Disease and Chronic Endodontic Infection. Is There an Association? A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2021;18(17).*
11. *Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990-2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet. 2012;380(9859):2224-60.*
12. *Kuzekanani M, Gutmann JL. Latest Concepts in the Endodontic Management of Patients with Cardiovascular Disorders. Eur Endod J. 2019;4(2):86-9.*
13. *Halboub E, Al-Maswary A, Mashyakhy M, Al-Qadhi G, Al-Maweri SA, Ba-Hattab R, et al. The Potential Association Between Inflammatory Bowel Diseases and Apical Periodontitis: A Systematic Review and Meta-Analysis. Eur Endod J. 2024;9(1):8-17.*
14. *Cintra LTA, Gomes MS, da Silva CC, Faria FD, Benetti F, Cosme-Silva L, et al. Evolution of endodontic medicine: a critical narrative review of the interrelationship between endodontics and systemic pathological conditions. Odontology. 2021;109(4):741-69.*
15. *Khalighinejad N, Aminoshariae MR, Aminoshariae A, Kulild JC, Mickel A, Fouad AF. Association between Systemic Diseases and Apical Periodontitis. Journal of endodontics. 2016;42(10):1427-34.*
16. *Segura-Egea JJ, Martin-Gonzalez J, Castellanos-Cosano L. Endodontic medicine: connections between apical periodontitis and systemic diseases. International endodontic journal. 2015;48(10):933-51.*
17. *Ahmed GM, El-Baz AA, Hashem AA, Shalaan AK. Expression levels of matrix metalloproteinase-9 and gram-negative bacteria in symptomatic and asymptomatic periapical lesions. Journal of endodontics. 2013;39(4):444-8.*
18. *Gomes MS, Blattner TC, Sant'Ana Filho M, Grecca FS, Hugo FN, Fouad AF, et al. Can apical periodontitis modify systemic levels of inflammatory markers? A systematic review and meta-analysis. Journal of endodontics. 2013;39(10):1205-17.*
19. *Cuschieri S. The STROBE guidelines. Saudi J Anaesth. 2019;13(Suppl 1):S31-s4.*
20. *Segura-Egea JJ, Castellanos-Cosano L, Velasco-Ortega E, Ríos-Santos JV, Llamas-Carreras JM, Machuca G, et al. Relationship between smoking and endodontic variables in hypertensive patients. Journal of endodontics. 2011;37(6):764-7.*
21. *An GK, Morse DE, Kunin M, Goldberger RS, Psoter WJ. Association of Radiographically Diagnosed Apical Periodontitis and Cardiovascular Disease: A Hospital Records-based Study. Journal of endodontics. 2016;42(6):916-20.*
22. *González-Navarro B, Segura-Egea JJ, Estrugo-Devesa A, Pintó-Sala X, Jane-Salas E, Jiménez-Sánchez MC, et al. Relationship between Apical Periodontitis and Metabolic Syndrome and Cardiovascular Events: A Cross-Sectional Study. J Clin Med. 2020;9(10).*
23. *Orstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endodontics & dental traumatology. 1986;2(1):20-34.*
24. *Correia-Sousa J, Madureira AR, Carvalho MF, Teles AM, Pina-Vaz I. Apical periodontitis and related risk factors: Cross-sectional study. Rev Port Estomatol Med Dent Cir Maxilofac. 2015;56(4):226-32.*

25. Melo L, Ferreira I, Lacet G, Braga AC, Pina-Vaz I. Apical periodontitis and oral status in patients with different systemic conditions and smoking habits in Portuguese population. Revista Endodoncia. 2017;35(-):10-22.
26. Rocha JS, Braga AC, Carvalho MF, Pina-Vaz I. Prevalence of apical periodontitis and endodontic treatment in an adult portuguese population. Arch Oral Res. 2012;8:219-27.
27. Diogo P, Palma P, Caramelo F, Marques dos Santos JM. Estudo da prevalência de periodontite apical numa população adulta portuguesa. Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial. 2014;55(1):36-42.
28. Poyato-Borrego M, Segura-Egea JJ, Martín-González J, Jiménez-Sánchez MC, Cabanillas-Balsera D, Areal-Quecuty V, et al. Prevalence of endodontic infection in patients with Crohn´s disease and ulcerative colitis. Medicina oral, patologia oral y cirugia bucal. 2021;26(2):e208-e15.
29. Razdan A, Jungnickel L, Schropp L, Vaeth M, Kirkevang LL. Trends of endodontic and periapical status in adult Danish populations from 1997 to 2009: A repeated cross-sectional study. International endodontic journal. 2022;55(2):164-76.
30. Dutta A, Smith-Jack F, Saunders WP. Prevalence of periradicular periodontitis in a Scottish subpopulation found on CBCT images. International endodontic journal. 2014;47(9):854-63.
31. Meirinhos J, Martins JNR, Pereira B, Baruwa A, Gouveia J, Quaresma SA, et al. Prevalence of apical periodontitis and its association with previous root canal treatment, root canal filling length and type of coronal restoration - a cross-sectional study. International endodontic journal. 2020;53(4):573-84.
32. De Moor RJ, Hommez GM, De Boever JG, Delmé KI, Martens GE. Periapical health related to the quality of root canal treatment in a Belgian population. International endodontic journal. 2000;33(2):113-20.
33. Al-Omari MA, Hazaa A, Haddad F. Frequency and distribution of root filled teeth and apical periodontitis in a Jordanian subpopulation. Oral surgery, oral medicine, oral pathology, oral radiology, and endodontics. 2011;111(1):e59-65.
34. Paes da Silva Ramos Fernandes LM, Ordinola-Zapata R, Húngaro Duarte MA, Alvares Capelozza AL. Prevalence of apical periodontitis detected in cone beam CT images of a Brazilian subpopulation. Dentomaxillofac Radiol. 2013;42(1):80179163.
35. Caplan DJ, Pankow JS, Cai J, Offenbacher S, Beck JD. The relationship between self-reported history of endodontic therapy and coronary heart disease in the Atherosclerosis Risk in Communities Study. Journal of the American Dental Association (1939). 2009;140(8):1004-12.
36. Gomes MS, Hugo FN, Hilgert JB, Sant'Ana Filho M, Padilha DM, Simonsick EM, et al. Apical periodontitis and incident cardiovascular events in the Baltimore Longitudinal Study of Ageing. International endodontic journal. 2016;49(4):334-42.
37. Joshipura KJ, Pitiphat W, Hung HC, Willett WC, Colditz GA, Douglass CW. Pulpal inflammation and incidence of coronary heart disease. Journal of endodontics. 2006;32(2):99-103.
38. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. Journal of endodontics. 2008;34(3):273-9.
39. Patel S, Brown J, Semper M, Abella F, Mannocci F. European Society of Endodontology position statement: Use of cone beam computed tomography in Endodontics: European Society of Endodontology (ESE) developed by. International endodontic journal. 2019;52(12):1675-8.
40. McHugh ML. Interrater reliability: the kappa statistic. Biochemia medica. 2012;22(3):276-82.
41. Buonavoglia A, Pellegrini F, Lanave G, Diakoudi G, Lucente MS, Zamparini F, et al. Analysis of oral microbiota in non-vital teeth and clinically intact external surface from patients with severe periodontitis using Nanopore sequencing: a case study. J Oral Microbiol. 2023;15(1):2185341.
42. Liccardo D, Cannavo A, Spagnuolo G, Ferrara N, Cittadini A, Rengo C, et al. Periodontal Disease: A Risk Factor for Diabetes and Cardiovascular Disease. International journal of molecular sciences. 2019;20(6).
43. Cotti E, Mercuro G. Apical periodontitis and cardiovascular diseases: previous findings and ongoing research. International endodontic journal. 2015;48(10):926-32.
44. World Health Organization cardiovascular disease risk charts: revised models to estimate risk in 21 global regions. Lancet Glob Health. 2019;7(10):e1332-e45.
45. Sánchez-Domínguez B, López-López J, Jané-Salas E, Castellanos-Cosano L, Velasco-Ortega E, Segura-Egea JJ. Glycated hemoglobin levels and prevalence of apical periodontitis in type 2 diabetic patients. Journal of endodontics. 2015;41(5):601-6.
46. Cabanillas-Balsera D, Segura-Egea JJ, Bermudo-Fuenmayor M, Martín-González J, Jiménez-Sánchez MC, Areal-Quecuty V, et al. Smoking and Radiolucent Periapical Lesions in Root Filled Teeth: Systematic Review and Meta-Analysis. J Clin Med. 2020;9(11).
47. Segura-Egea JJ, Jiménez-Pinzón A, Ríos-Santos JV, Velasco-Ortega E, Cisneros-Cabello R, Poyato-Ferrera MM. High prevalence of apical periodontitis amongst smokers in a sample of Spanish adults. International endodontic journal. 2008;41(4):310-6.
48. Krall EA, Abreu Sosa C, Garcia C, Nunn ME, Caplan DJ, Garcia RI. Cigarette smoking increases the risk of root canal treatment. Journal of dental research. 2006;85(4):313-7.
49. Fuchs FD, Whelton PK. High Blood Pressure and Cardiovascular Disease. Hypertension. 2020;75(2):285-92.
50. Jiménez-Sánchez MC, Cabanillas-Balsera D, Areal-Quecuty V, Velasco-Ortega E, Martín-González J, Segura-Egea JJ. Cardiovascular diseases and apical periodontitis: association not always implies causality. Medicina oral, patologia oral y cirugia bucal. 2020;25(5):e652-e9.